



Winter High Tunnel Spinach Production

A Guide for Commercial and Home Growers

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Introduction

High tunnel greenhouses have become an essential tool for small-scale commercial vegetable growers, particularly in the northern United States. The relatively low-cost greenhouses provide improved growing conditions during the summer and extend the season in the spring and fall. During the winter the greenhouses are typically not heated and sit idle. There is growing interest in using the high tunnels to produce cold-hardy vegetables during the winter months in order to improve returns from the capital invested in the high tunnel structure.



Spinach is a winter crop option that is becoming increasingly popular with both growers and consumers. Winter-grown spinach tends to have thicker leaves and a higher sugar content that consumers respond well to. Input costs are relatively low and there is good opportunity for profit for growers. However, like any crop, winter spinach requires careful planning and management.

The information presented in this guide is based on research and grower experiences from northern Wisconsin. As such, the information will be most relevant for growers in similar climates across the northern United States and southern Canada.

Variety Selection

With 60+ varieties of spinach available to growers it can be a challenge to choose the right variety, and even more so for winter high tunnel production as production trial information is limited. With growing interest in production there have been some recent trials, however. Researchers in New Hampshire found no cumulative season yield differences among the six varieties they tested but did find that 'Gazelle' and 'Emporer' had higher sugar content than other varieties (Orde and Sideman, 2016). The researchers recommend 'Corvair' based on appearance and overall production. Research in Wisconsin found 'Renegade', 'Corvair', and 'Space' to be higher yielding than 'Emporer', 'Banjo', and 'Responder', though yield differences among the six varieties were small (Fischbach and Dawson, 2019). Besides yield, other important attributes



Photo 1. A high tunnel greenhouse in December in Washburn, WI with the glow of LED lights. High tunnels are great tool for growing produce in the spring, summer, and fall, but they can also work well for growing spinach in the winter months.

to consider when choosing a spinach variety are leaf type and disease resistance. Semi-savoy leaf types with an upright growth habit, such as ‘Corvair’ and ‘Emperor’ performed well in both the New Hampshire and Wisconsin trials. The upright growth habit makes the spinach easier to pick, especially in the winter as the cold temperatures tend to result in more prostrate plants. Downy mildew can be a major problem in winter spinach and choosing resistant varieties is important. There are many races of the downy mildew fungus and if downy mildew occurs it is important to have the race identified so that the right variety can be chosen for the next round of production. Table 1 shows known race resistance for a range of spinach cultivars.

Planting Dates

In general, winter spinach is seeded in the fall (Sept-Oct) with a harvest or two likely before January 1. No harvests typically occur during deep winter (Jan-Feb) and the bulk of production occurs in Mar-May. Figure 1 shows the cumulative spinach yield at three different high tunnel locations in northern Wisconsin. At all three locations 80% or more of the total season production occurred Mar-May (Fischbach and Dawson, 2019).

Fall planting date can have a significant impact on fall season and total season yields. The New Hampshire study compared the yields of three different varieties transplanted roughly every 10 days from September 20 through November 9. The September plantings yielded nearly three times as much as the late-October plantings due mainly to additional harvests in the fall before the plants went dormant over deep winter. However, environmental differences across years also impact yields as the September plantings yielded only twice as much as the October plantings in the first year of the trial, which was considerably cooler. The authors recommend planting in mid- to late-September if a November harvest is wanted, otherwise the spinach can be planted into October, but most of the production won’t occur until March and April. Trials in Wisconsin found similar results with September planted spinach yielding more than October planted spinach. The yield differences weren’t quite as large in the Wisconsin trials likely due to a cooler fall climate in northern Wisconsin compared to New Hampshire.

Direct Seeding or Transplanting

Spinach can either be direct seeded or seeded into plug trays and transplanted. Direct seeding is the less expensive method, but spinach germination can be variable and there is no room for error with planting winter spinach. If the planting window is missed due to a failed seeding it can mean missing the entire winter season. Starting plants in plug trays ensures that the growing space is fully stocked and that plant spacing is optimized. It also can mean the summer crop in the high tunnel can be grown at least another two weeks while the spinach is growing in the plug trays. Studies in Utah and New Hampshire used 128-cell plug trays with good success. The Wisconsin

Variety	Race Resistance
Acadia	1-13, 15, 16
Bandicoot	1-16, IR-17
Bonobo	1-9, 11-17, IR-10
Caladonia	1-14
Callisto	1-14, 16, 17
Carmel	1-11, 13, 15
Coati	1-15, 17
Corvair	1-11, 13
Dromedary	1, 13, 15
El Caballo	1-6, 8-17; IR-7
Emperor	1-10
Escalade	1-14, 16
Flamingo	1-11
Fresno	1-15
Gazelle	1-13
Gorilla	1-15, 17
Hammerhead*	1-12, 14-16
Kiowa	1-17
Kolibri	1-9, 12-15, 17, IR-10,11
Kookaburra	1-13, 15
Mandolin	1-12, 14-16
Marten	1-15, 17
Meekat	1-15, 17
Nevada	1-17
Pigeon	1-13, 15
Platypus	1-15, 17
Red Kitten	1-13, 15
Reflect	1-11
Regiment	1-7
Regor	1-17
Renegade	1-7
Seaside	1-12
Shelby	1-13, 15, 16
Silverwhale	1-9, 11-16, IR-10
Space	1-3, 5, 6, 8, 11, 12
Spoonbill	1-16; IR-17
SV 2157	1-13, 15, 16
Tasman*	1-12, 14-16
Toucan	1-13, 15, 16
Tyee*	1-3
Violin	1-12, 14
Virgo	1-15, IR-16
Whale	1-5, 7-9, 12-14, IR-16
Woodpecker	1-15

Table 1. Downy mildew race resistance of spinach cultivars. (Adapted with permission from Dr. Meg McGrath, Cornell University)

trials used 216-cell plug trays and also had good success even with the October 30 transplant date. If the goal is fall spinach production, then using larger plugs to grow larger transplants is recommended. If the goal is late-winter and spring production, then 216-cell plug trays are recommended as it cuts down on soil and growing space costs.

Plant Spacing

Spinach yields and leaf quality are both affected by plant spacing. High densities can increase yields, but may result in small leaves or more disease growth. The Utah study evaluated yield and leaf quality at different between-row spacings and found 4" spacing to provide the best balance of yield and leaf quality. Based on those results, the Wisconsin trials used 4" in-row and 4" between-row spacings with good success. Photo 2 shows plants at the 4" spacing immediately after harvest.

Soil Fertility

Spinach is a fast-growing crop that requires adequate fertility to sustain season-long production. A soil test prior to transplanting is recommended in order to address any deficiencies. Target soil numbers are pH – 6.0, Phosphorus – 31-45ppm, and Potassium – 111-140ppm. Like with all crops, managing nitrogen with spinach can be tricky but, generally, 80 lbs of actual N is recommended per acre to meet the crop need. This translates to 0.03 oz of actual N per square foot. It is best to fertilize winter spinach prior to planting, as it can be hard to deliver fertilizer to growing spinach in general, and especially during the winter months. To figure out how much fertilizer to apply it is necessary to first know the N percentage in the chosen fertilizer. For example, if pelleted chicken manure (2% N) is incorporated prior to planting, then 1.5 oz of the fertilizer per square foot would need to be applied. A 96' x 3' bed of spinach would therefore require 27 lbs of the pelleted chicken manure.

Harvesting

High tunnel spinach is harvested by pinching individual leaves or by clipping the entire plant. Pinching individual leaves results in the best product quality but is labor-intensive (Photo 2). Clipping or scissor-cutting entire plants or beds is faster but results in cut leaves in the harvested spinach and damaged leaves left behind that develop with a deformed shape. Winter-grown spinach tends to have larger and thicker leaves than outdoor summer-grown spinach, which combined with higher market prices, makes hand

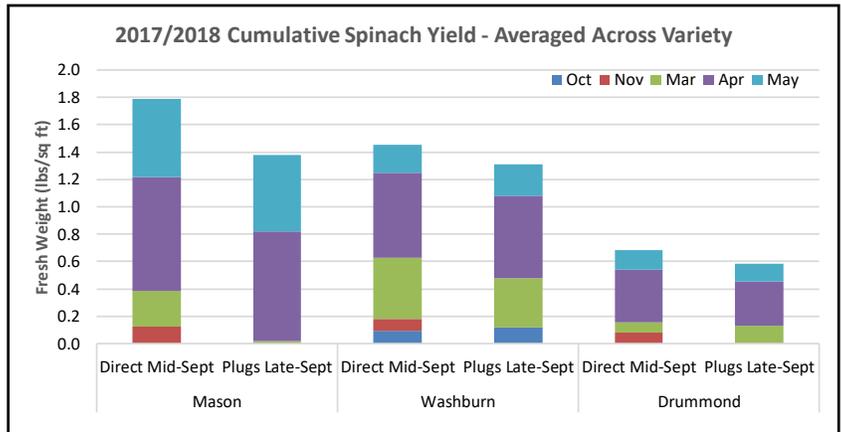


Figure 1. Cumulative spinach yield grown in unheated high tunnels at three locations in northern Wisconsin. Most production in unheated high tunnels occurs in April and May. Not surprisingly, soil quality greatly affects spinach production as the Mason site with high quality loam yielded significantly more than the Drummond site with sandy soil.



Photo 2. Transplanted spinach as compared to direct seeded is more expensive but it allows planting later in the fall and an optimized 4" plant spacing as shown here. These three middle rows were harvested by pinching individual leaves, thus keeping the younger leaves intact and free to grow for a return harvest.

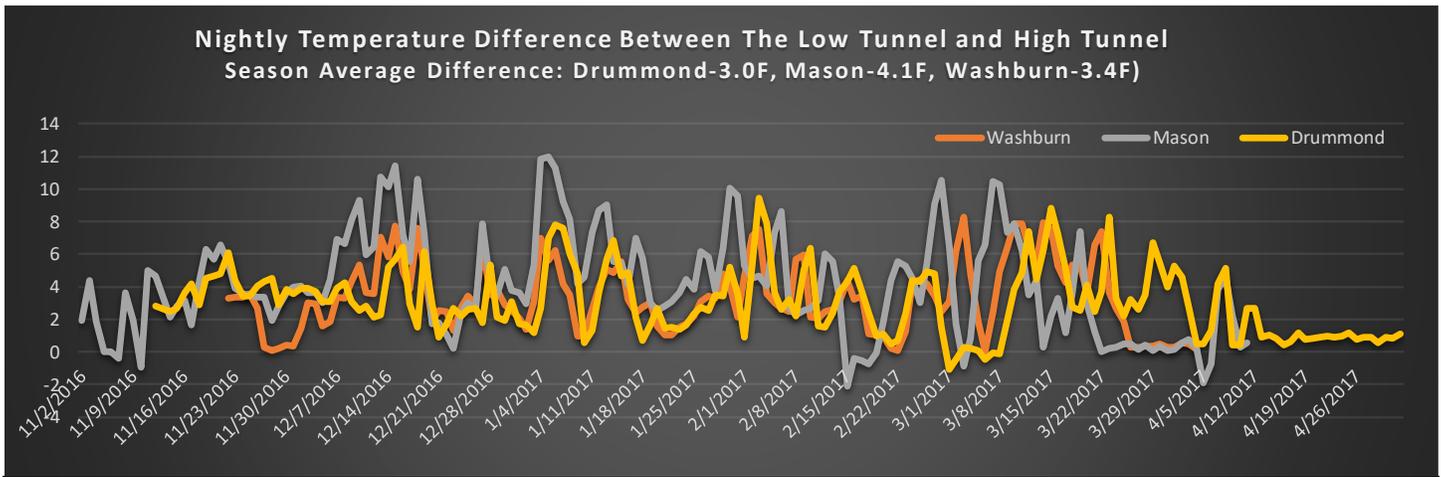


Figure 2. The nightly (7pm-7am) average temperature difference between the high tunnel and low tunnel during the winter of 2016/2017 at three locations in northern Wisconsin. With the exception of a few nights, the average nightly temperature in the low tunnels was warmer during the winter than in the high tunnels. However, the low tunnels alone are not sufficient to keep the spinach from going dormant in January and February.

harvesting individual leaves viable. Growers report that the larger winter leaves can confuse customers who are used to eating baby spinach in the bagged salad mixes common in most grocery stores these days. As such, growers may need to educate customers about the larger leaves. That said, growers often report that customers rave about the winter spinach given its sweeter taste.

Using Low Tunnels To Moderate Temperatures

The optimal temperature range for spinach is 60-75F, but it can tolerate very cold temperatures. Growth stops below 36F, and if sufficiently conditioned to cold temperatures, can survive temperatures below 0F. In the Wisconsin trials, temperatures reached -8F in the high tunnel and the spinach survived just fine. However, the cold temperatures in northern climates put the spinach in dormancy which is why there is little to no growth December through February.

Some growers will use low tunnels within the high tunnels to provide extra heat retention with the goal of reducing temperature fluctuations and increasing nighttime minimum temperatures. These low tunnels are constructed using hoops or wooden frames with plastic film or floating cow cover fabric (Photo 3). The effect of low tunnels was evaluated at three locations in northern Wisconsin. On average, the minimum nightly temperatures in the low tunnels were 3.0, 3.4, and 4.1 degrees F warmer than in the high tunnels at each respective location (Figure 2). This isn't enough to keep spinach from going dormant in the depth of winter, but improves production especially in November, March, and April by shortening the dormancy period and adding growing degree days. At the coldest of the three locations in the trials, the low tunnels added 300 growing degree days Nov-Apr in 2016/2017 and 200 growing degree days Nov-Apr in 2017/2018. In a trial in Utah, low tunnels doubled production in the fall growth phase and increased production by 89% in the spring growth phase. The low tunnels, however, can increase humidity levels resulting in a greater chance of disease. Overheating is also a possibility, especially in the fall and spring. For this reason, low tunnel covers are typically removed



Photo 3. Low tunnels are used to trap additional heat during the nighttime. They can be built any number of ways such as with guy wires and floating row covers (top), wooden frames and frost blankets (middle), or wire hoops with frost blankets (bottom).

on sunny days.

Expected Yields and Harvest Frequency

Season total yields are highly variable across years, planting date, and locations. The New Hampshire trials had yields ranging from 1.3 lbs/sq ft from spinach planted in September in a warm year to as low as 0.3 lbs/sq ft from spinach planted in November in a cool year. In the Wisconsin variety trials yields ranged from 1.8 lbs/sq ft to 0.6 lbs/sq ft. In general, a total season yield of 1.0 lbs/sq ft is a reasonable estimate for enterprise budgeting.

Adding Supplemental Heat and Light

Trials were conducted at three locations in northern Wisconsin over two winters to evaluate the effect of adding supplemental heat and/or light within the low tunnels. The researchers used heated forced air to maintain minimum temperatures of 32F and 45F and LED lights to maintain a 12-hour daylength over the winter months (Photo 4). Adding just the

supplemental heat had no consistent effect on season-long production in part because the heating system wasn't sufficient to keep the temperatures warm enough to prevent the plants from going dormant but also because of the lack of sunlight during the winter months. During the prime growing months of October and April there was sufficient natural heat such that the supplemental heat didn't add anything. In contrast, in the Utah study adding supplemental heat with heating cables in the soil increased fall and spring production by nearly 0.5 lbs/sq ft. But, the study did not present data as to the return on investment for the heating cables and electricity.

Adding supplemental light in the Wisconsin trials not only didn't increase season-total spinach yields, but it tended to decrease yields for a couple of reasons. The supplemental light, especially in combination with the supplemental heat, resulted in larger but thinner leaves that had lower weights. The light also resulted in earlier bolting in the spring. Because most growth occurred in April and October when days are already long, adding supplemental light had little impact. Clearly, adding supplemental heat and light will increase yields, but enough must be added to have an impact and if the goal is Dec-Feb production then the spinach should be grown in a more insulated structure than a high tunnel greenhouse. The full results of the Wisconsin heat/light trials are presented in the research bulletin, "The Effect of Planting Date and Supplemental Heat and Light On High Tunnel Winter Spinach Production" and available at the Bayfield County UW-Extension website.

Disease and Pest Issues

Conditions in a winter greenhouse can be dark and humid, which is conducive for water-loving fungal pathogens. Both downy mildew and heterosporium occurred in each location in the Wisconsin trials (Photo 5). Controlling these pathogens, especially organically, can be a challenge. It requires careful scouting to remove inoculum when found to prevent widespread infection. If the disease does spread, then eradicants such as peroxyacetic acid or copper can be used to kill spores. But, generally the best control strategy is prevention by venting the greenhouse to remove humidity and using disease resistant varieties.

Aphids effectively end the growing season in the spring as the populations explode in late-April and early-May. However, the populations typically spike at the same time as the spinach bolts so the plants are



Photo 4. The Wisconsin trials evaluated the effect of supplemental heat and light on production of winter spinach planted at four different dates and at three different locations. Wooden frames were used to support LED lights and heated air was blown down poly tubes within each low tunnel to add the heat.



Photo 5. The fearsome foursome of winter spinach pests: heterosporium (left), downy mildew (center-left), aphids (center-right), mice (right). Like any other crop, winter spinach has pest issues, but by far the most concerning are fungal disease that thrive in the moist environment. Planting disease resistant varieties, providing ventilation on warm days, and having a plan if disease is found are all key for winter spinach production.

removed at that point anyway. Removing all other vegetation from within the high tunnel can help limit aphids, but generally growers should expect aphids in the spring.

Voles and other rodents can cause problems with winter spinach due to the warmer conditions in the high tunnel. Careful monitoring should be conducted and trapping used as necessary to remove the mice.

The Economics of Winter Spinach Production

Table 2 shows the revenue, material costs, labor, and assumptions for a single 288 sq ft bed of spinach (96'x3'). The 96' bed is 3' wide with 9 rows spaced 4" apart with 4" in-row plant spacing (9 plants per sq ft). Revenue is based on a season total production of 1 lb/sq ft (288 lbs/bed) with all the spinach sold wholesale at \$4.50/lb. The spinach is started in 128-cell plug trays in early-September and transplanted in late-September. There are seven harvests per year with roughly 40 lbs per bed per harvest. As shown in Table 2, the cost of production is almost entirely labor. If the labor is hired, the net income to the farm owner is \$278 per bed.

However, if the farm owner is providing the labor, the return to labor is a healthy \$1265 per bed.

Not included in these numbers are the capital costs associated with the high tunnel, low tunnels, frost-free hydrant, or washing facilities. The assumption is winter spinach production is an "add-on" enterprise that is making use of idle

Revenue	Per Bed	Assumptions
Spinach-wholesale	\$1,296.00	\$4.50/lb wholesale, 288 lbs/bed per season
Variable Costs	Each Flat	Per Bed
Transplants (Flats)		
Seed	\$ 0.10	\$ 2.19 \$8.15/10,000 seeds, 21 flats, 2688 seeds/bed
128-cell flats	\$ 0.30	\$ 6.25 \$1.19 each, 4 uses
Trays	\$ 0.16	\$ 3.32 \$0.63 each, 4 uses
Germination mix	\$ 0.46	\$ 9.63 \$12.50/3 cu ft bag, 0.11 cu ft/flat
Planting Beds		
Fertilizer		\$ 9.72 pelleted chicken manure, \$0.36/lb, 27 lbs/bed
Labor		
Bed preparation		\$ 7.50 30 minutes/bed, \$15/hr
Planting labor	\$ 1.50	\$ 31.50 10 trays/hr, \$15/hr
Plug labor		\$ 97.50 15 minutes/day, 26 days, \$15/hr
Transplanting	\$ 5.00	\$ 105.00 3 trays/hr, \$15/hr
Watering		\$ 12.50 10 times per season, 5 minutes/time, \$15/hr
Low tunnel management		\$ 275.00 10 minutes/day, 110 days, \$15/hr
Weeding		\$ 12.00 2 times per season, 20 minutes/bed, \$15/hr
Harvesting		\$ 236.25 2.25 hrs/harvest, 7 harvests/yr, \$15/hr
Washing		\$ 210.00 7 harvests, 40 lbs/harvest, 20 lbs/hr washing/bagging, \$15/hr
Total Variable Costs		\$1,018.36
Net Income		\$ 277.64
Return to Labor		\$1,264.89 net income plus labor costs

Table 2. Revenue and variable costs for a 96'x3' bed of high-tunnel winter spinach production.

facilities, facilities that would likely already be in place for summer production. Marketing and packaging costs are also not included in these numbers.

Obviously, production costs will vary considerably from farm to farm, especially labor, so operators are encouraged to determine their own numbers. Operators must also judge the risks of winter spinach, especially the potential for catastrophic losses from foliar disease. Winter spinach production is becoming more popular and is likely an enterprise worth considering for operations looking for some winter revenue.

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